Dutton Street over Portage Creek
Job No. C0803
Single Span Side-by-Side Prestressed Concrete Box-Beam Bridge
Bridge Load Rating

Created by: LYL
Checked by: AZT 10/31/08
Date: 9/9/2008

Property Input

Bridge Properties:

Bridge Length (C/L BRG to C/L BRG)	Length =	35	ft
Deck Thickness	t_{deck} =	6	in
Crossection Area of Composite Beam	A_{comp} =	648	in^2
Momnet of Inertia of Composite Beam	I_{comp} =	23328	in^4
Distance from beam top to NA of Composite Beam	y_{tcomp} =	3	in
Distance from beam bottom to NA Composite Beam	y_{bcomp} =	9	in
Composite Eccentricity of Strands	e_{cgs} =	7	in
Distribution Factor for Superimposed Dead Loads ($1/No_{beams}$)	DF_D =	0.06	
Number of traffic lanes	n_{lanes} =	3	
Weight of Concrete	WT_c =	150	lb/ft^3
Grout Width	W_{grout} =	1.5	in
Barrier Type — Aesthetic Parapet with Metal Railing	Type =	None	
Weight of Barrier	$WT_{barrier}$ =	350	lb/ft
Weight of Deck	WT_{deck} =	4296.88	lb/ft
Sidewalk Thickness	$t_{sidewalk}$ =	9.50	in
Sidewalk Width	$W_{sidewalk}$ =	7.65	ft
Weight of Sidewalk	$WT_{sidewalk}$ =	907.94	flb/ft

Beam Properties:

Number of Beams	No_{beam} =	18	
Box Beam Width	b =	36	in
Beam Depth	h =	12	in
Web Thickness	t_{web} =	0	in
Flange Thickness	t_{flange} =	0	in
Distance from beam top to NA	y_t =	6.04	in
Distance from beam bottom to NA	y_b =	5.96	in
Crossection Area of Beam	A =	424	in^2
Momemt of Inertia	I =	5120	in^4
Composite Strength of Beam	f'c =	5000	psi
Poisson's Ratio	v =	0.2	
Area of Prestressing Strand	A_{ps} =	2.356	in^2
Yield Strength of Pre-Stress Strands	$fstar_y$ =	243	ksi
Pre-Stress Strands after Losses	F_{ps} =	157.5	ksi
Eccentricity of Strands	e_c =	4	in

Property Input

Calculated Properties:

Live Load Distribution Factor: (AASHTO 3.23.4)

Bridge Width = W_{bridge} = 57.29 ft

Saint-Venant torsion constant "J" (Box Beam only)

$J = 2 \times (b)^2 \times (h)^2 / b + h$

$J =$ 7776.00 in^4

$K = [(1 + v) \times (I / J)]^{1/2}$ $K =$ 0.89

Width to Length Ratio
If W / L less than 1, use calculate C $W / L =$ 1.64
If W / L is greater than or equal to 1, use C equal to K

$C = K \times (W_{bridge} / \text{Length})$ $C =$ 1.46

Width to length Ratio, C = 0.89

$D = (5.75 - 0.5 \times n_{lanes}) + 0.7 \times n_{lanes} \times (1 - 0.2 \times C)^2$

$D =$ 5.67

Live Load Distribution Factor, DF_L

$DF_L = b / 2 \times D$ **DF_L = 0.26**

Total Prestress Force:

Pi = Aps x Fps **Pi = 371.07 k**

Property Input

Radius of Gyration Beam:

$r^2 = I / A$ **r^2 = 12.08 in^2**

Radius of Gydration Composite:

$r^2_{comp} = I_{comp} / A_{comp}$ **r^2_{comp} = 36.00 in^2**

Modulus Ratio Steel/Conc:

$n_s = 28000000 / 33 \times 150^{1.5} \times f'c^{1/2}$ **n_s = 6.53**

Vehicle Impact from AASHTO 3.8.2.1:

Impact = 50 / (Length + 125) < 0.3 **Impact = 0.30**

Applied Loads

Dead Loads

Weight of Barriers for Entire Width	Barriers =	700.00	lb/ft
Weight of Beam	Beam =	441.67	lb/ft
Weight of Deck per Beam	Deck =	238.72	lb/ft
Weight of Sidewalk for Entire Width	Sidewalk =	1815.89	lb/ft

Non-Composite Beam
Maxmum Moment occurred at mid-span

Dead Load Moment (deck only)

M_{Dslab} = (Deck) x Length ^{2} / 8 **M_{Dslab} = 36.55 ft*k**

Total Dead Load Moment

M_D = (Beam + Deck) x Length^2 / 8 **M_D = 104.18 ft*k**

Maximum Shear occurres at end of beam

Total Dead Load Shear

V_D = (1/2) x (Beam + Deck) x Length x {[Length / 2 - (y_{bcomp} + y_{tcomp} + t_{deck}) / 2] / (Length / 2)}

V_D = 11.40 k

Composite Beam
Dead Load Moment

M_{Dcomp} = (Barriers + Sidewalk) x Length^2 x DF_D / 8 **M_{Dcomp} = 21.40 ft*k**

Dead Load Shear

V_D = (1/2)x(Barrier + Sidewalk)xLengthxDF_Dx{[Length/2 - (y_{bcomp} + y_{tcomp} + t_{deck})/2] / (Length/2)}

V_{Dcomp} = 2.34 k

Applied Loads

Pre-stressing
(Applied on Continuous Spans Only)

Ms = 0 ft*k

Vs = 0 k

Fs = 0 ksi

Live Loads

HS20 Standard Truck

Live Load Moment from Table 10.9 — 361 ft*k
Live Load Shear from Table 10.21 — 52.8 k

$M_L = 361 \times DF_L$ $\quad M_L = 95.51$ ft*k
$V_L = 52.8 \times DF_L$ $\quad V_L = 13.97$ k

Michigan Legal Loads
1-unit Vehicle, 2-unit Vehicle, 3-unit Vehicle & Michigan # 18 Truck
were considered to provide the worst shear and moment loading conditions.

	Truck NO	Moment (ft*k)	MDOT Table	Shear (k)	MDOT Table	DF_L	M_{LM1-4} (ft*k)	V_{LM1-4} (k)
1-unit vehicle	5	361	10.4	50.5	10.16	0.26	95.51	13.36
2-unit vehicle	17	548	10.5	68.3	10.17	0.26	144.98	18.07
3-unit vehicle	23	471	10.6	62	10.18	0.26	124.61	16.40
Mich #18 Truck	18	548	10.5	67.8	10.17	0.26	144.98	17.94

Vehicle Weight

From MDOT Fig 2.1 & 2.2

	W_{MF} (k)	W_{VF} (k)
Federal Truck	72	72
1-unit Truck	84	84
2-unit Truck	151.4	151.4
3- unit Truck	154	154
Mich # 18 Truck	154	154

Stresses on Beam & Strand

Stresses on Beam

Dead Load Compression Stresses (Top of Section)

$F_{dt} = (- M_D \times y_t / I) + (-M_{dcomp} \times y_{tcomp} / I_{comp})$ **F_{dt} = -1.51 ksi**

Dead Load Tension Stress (Bottom of Section)

$F_{db} = (M_D * y_b / I) + (M_{Dcomp} * y_{bcomp} / I_{comp})$ **F_{db} = 1.55 ksi**

Compression stress due to HS-20

$F_{lt} = - (1+ \text{Impact}) \times M_L \times y_{tcomp} / I_{comp}$ **F_{lt} = -0.19 ksi**

Tension stress due to HS-20

$F_{lb} = (1+ \text{Impact}) \times M_L \times y_{bcomp} / I_{comp}$ **F_{lb} = 0.57 ksi**

Prestress Concrete Compression

$F_{pb} = (- P_i / A) \times (1+ (e_c \times y_b / r^2))$ **F_{pb} = -2.60 ksi**

Prestress Concrete Tension

$F_{pt} = (- P_i / A) \times (1 - (e_c \times y_t / r^2))$ **F_{pt} = 0.88 ksi**

Note: Consistency with the Michigan Bridge Analysis Guide has deviated,
Compression shall be taken as (-) and Tension as (+)

Stresses on Beam & Strand

Stresses in Prestressing Strand

Steel Stress due to Non-Composite Dead Load (Deck Only)

$f_{ds} = n_s \times (M_{Dslab} \times e_c / I)$ **f_{ds} = 2.24 ksi**

Steel Stress due to Composite Dead Load

$f_{dscomp} = n_s \times (M_{Dcomp} \times e_{cgs} / I_{comp})$ **f_{dscomp} = 0.50 ksi**

Steel Stress due to HS20

$f_{lscomp} = n_s \times ((1+ Impact) \times M_L \times e_{cgs} / I_{comp})$ **f_{lscomp} = 2.92 ksi**

Steel Stress due to 1 unit truck

$f_{sM1} = n_s \times ((1+ Impact) \times M_{LM1} \times e_{cgs} / I_{comp})$ **f_{sM1} = 2.92 ksi**

Steel Stress due to 2 unit truck

$f_{sM2} = n_s \times ((1+ Impact) \times M_{LM2} \times e_{cgs} / I_{comp})$ **f_{sM2} = 4.43 ksi**

Steel Stress due to 3 unit truck

$f_{sM3} = n_s \times ((1+ Impact) \times M_{LM3} \times e_{cgs} / I_{comp})$ **f_{sM3} = 3.81 ksi**

Steel Stress due to Michigan # 18 truck

$f_{sM4} = n_s \times ((1+ Impact) \times M_{LM4} \times e_{cgs} / I_{comp})$ **f_{sM4} = 4.43 ksi**

Load Capacity

Flexural Capacity

Strength Reduction factor and Material Properties

Prestressed Concrete beams with Bending Loads	$\phi =$	1	
Whitney Stress Block Distribution	$\beta_1 =$	0.8	
Ultimate Strength of Prestressing Strands	$f's =$	270	ksi
Factor for type of Prestressing Steel (AASHTO 9.17)	$\gamma_{star} =$	0.28	

Composition Section including (deck and shear keys)

$b_{comp} = b + W_{grouts}$ **$b_{comp} =$ 37.5 in**

$d_{comp} = h + t_{deck} - 2$ in **$d_{comp} =$ 16 in**

Reinforcement Ratio

$p_{star} = A_{ps} / (b_{comp} \times d_{comp})$ **$p_{star} =$ 0.0039**

Average stress at ultimate load

$fstar_{su} = f's \times (1-(\gamma_{star}/\beta_1)*(p_{star} \times f's / f'c))$ **$fstar_{su} =$ 249.96 ksi**

Compression Zone below Top Flange Check (AASHTO 9.17)

$a = (A_{ps} \times fstar_{su}) / (0.85 \times f'c \times b_{comp})$ **$a =$ 3.70 in**

if a > flange thickness, it requires T-beam analysis T-Beam Analysis

Maximum Amount of Reinforcement Check (AASHTO std spec 9.18.1)

$p_{star} \times fstar_{su} / f'c < 0.36 \times \beta_1 = 1$ 0.20 < 0.288

OK

Flexural Capacity (AASHTO eqn 9-13)

$\phi M_n = \phi \times [A_{ps} \times fstar_{su} \times d_{comp} \times (1- 0.6 \times (p_{star} \times fstar_{su} / f'c)]$

$\phi M_n =$ 692.73 ft*k

Load Capacity

Shear Capacity

Strength Reduction Factor	ϕ_v =	0.85	
	b' =	9	in
Area of the Shear Steel and Yield Strength			
2 # 4 bars	Av =	0.4	in^2
	fy =	60	ksi
Spacing between Stirrups		12	in
Limit at the edge of beam (AASHTO std spec 9.20.1.4)			
$\mathscr{X} = (h + t_{deck}) /2$	$\mathscr{X}$ =	**9**	**in**
Dead Load includes beam, deck , sidewalk distributed over bridge width			
W_{DL} = Beam +Deck + (Barriers + Sidewalk) x DF_D	W_{DL} =	**0.82**	**k/ft**
Bending Moment at distance x with dead loads			
$M_d = W_{DL} \times (\text{Length} - \mathscr{X}) /2$	M_d =	**10.53**	**ft*k**
Compressive Stress due to effective prestress force			
$f_{pe} = (- Pi / A_{comp}) \times (1+ (e_{cgs} \times y_{bcomp} / r^2_{comp}))$	f_{pe} =	**-1.57**	**ksi**
Stress at extreme fiber due to unfactored dead load			
$f_d = M_d \times y_{bcomp} / I_{comp}$	f_d =	**0.05**	**ksi**

Load Capacity

Calculation of Vci

VMratio = Length - 2 x $\mathscr{X}$ / $\mathscr{X}$ x (Length - $\mathscr{X}$) **VMratio = 1.30 1/ft**

Flexural cracking due to externally applied Load

$M_{cr} = I_{comp} / y_{comp} \times (6 \times (f'c^{1/2}) - f_{pe} - f_d)$ **M_{cr} = 421.25 ft*k**

$Vci = 0.6 \times f'c^{1/2} \times b' \times d_{comp} + V_D + V_{dcomp} + VM_{ratio} \times M_{cr}$

Vci = 569.22 k

Calculation of Vcw

$Vcw = (3.5 \times f'c^{1/2} + 0.3 \times F_{ps} \times A_{ps} / A_{comp}) \times b' \times d_{comp}$

Vcw = 60.38 k

Steel Contribution to Shear Capacity

$V_s = A_v \times f_y \times d_{comp} / \text{spacing}$ **Vs = 32.00 k**

Steel Shear Strength Check

$8 \times f'c^{1/2} \times b' \times d_{comp} > V_s$ OK

Shear Capacity

$\phi V_n = \phi_v \times (\min(Vcw, Vci) + Vs)$ **ϕV_n = 78.52 k**

Maximum Loads with Michigan Legal Load

Moment Limit

Moment Capacity that remains after dead loads are placed
(moment due to sidewalk and deck is being subtracted from ϕMn)

$Madd_{LL} = (\phi M_n - 1.3 \times (M_D + M_{dcomp}) + M_s) / (1.3 \times (1 + Impact))$

$Madd_{LL}$ = 313.29 ft*k

Live Load Moment per lane

$M_{LL} = Madd_{LL} / DF_L$ **M_{LL} = 1184.19 ft*k**

Shear Limit

Shear Capacity that remains after dead loads are placed
(Shear due to sidewalk and deck is being subtracted from ϕçn)

$Vadd_{LL} = (\phi V_n - 1.3 \times (V_D + V_{dcomp}) + V_s) / (1.3 \times (1 + Impact))$

$Vadd_{LL}$ = 35.89 k

Live Load Shear per lane

$V_{LL} = Vadd_{LL} / DF_L$ **V_{LL} = 135.67 k**

Service Load Limit

$f_{LL} = (0.9 \times fstar_y - (f_{ds} + f_{dscomp} + F_{ps})) / (1 + Impact)$

f_{LL} = 44.97 ksi

$serviceMadd_{LL} = (f_{LL} \times I_{comp}) / (n_s \times e_{cgs})$ **$serviceMadd_{LL}$ = 1911.96 ft*k**

Live Load Moment per lane

$serviceM_{LL} = serviceMadd_{LL} / DF_L$ **$serviceM_{LL}$ = 7226.83 ft*k**

Inventory Rating

Federal Level

If the Rating Factor (RF) is greater than 1, then the bridge has enough capacity for the load.

Concrete Tension Check

$RF_1 = 6 \times f'c^{1/2} - (F_{db} + F_{pb} + F_s) / F_{lb}$ **RF_1 = 2.56**

Concrete Compression

$RF_2 = (-0.6 \times f'c - (F_{dt}+F_{pt}+F_s)) / F_{lt}$ **RF_2 = 12.36**

$RF_3 = (-0.4 \times f'c - (1/2) \times (F_{dt} + F_{pt} + F_s)) / F_{lt}$ **RF_3 = 8.79**

Prestress Steel Tension

$RF_4 = (0.8 \times fstar_y - (f_{ds} + f_{dscomp} + F_{ps} + F_s)) / f_{lscomp}$

RF_4 = 11.70

Flexural Strength

$RF_5 = \{ \phi Mn - [1.3 \times (M_D + M_{Dcomp}) + M_s]\} / [2.17 \times M_L \times (1 + \text{Impact})]$

RF_5 = 1.97

Shear Strength

$RF_6 = \{ \phi V_n - [1.3 \times (V_D + V_{Dcomp}) + V_s]\} / [2.17 \times V_L \times (1 + \text{Impact})]$

RF_6 = 1.54

Operating Rating

Federal Level

Flexural Strength

$RF_7 = \{ \phi Mn - [1.3 \times (M_D + M_{Dcomp}) + M_s]\} / [1.3 \times M_L \times (1 + Impact)]$

RF_7 = 3.28

Shear Strength

$RF_8 = \{ \phi V_n - [1.3 \times (V_D + V_{Dcomp}) + V_s]\} / [1.3 \times V_L \times (1 + Impact)]$

RF_8 = 2.57

Prestressing Steel Tension

$RF_9 = (0.9 \times fstar_y - (f_{ds} + f_{dscomp} + F_{ps} + F_s)) / f_{lscomp}$

RF_9 = 20.02

Michigan Level

1-Unit Vehicle
Flexural Strength

$RF_{7M1} = \{ \phi Mn - [1.3 \times (M_D + M_{Dcomp}) + M_s]\} / [1.3 \times M_{LM1} \times (1 + Impact)]$

RF_{7M1} = 3.28

Shear Strength

$RF_{8M1} = \{ \phi V_n - [1.3 \times (V_D + V_{Dcomp}) + V_s]\} / [1.3 \times V_{LM1} \times (1 + Impact)]$

RF_{8M1} = 2.69

Prestressing Steel Tension

$RF_{9M1} = (0.9 \times fstar_y - (f_{ds} + f_{dscomp} + F_{ps} + F_s)) / f_{sM1}$

RF_{9M1} = 20.02

Operating Rating

2-Unit Vehicle
Flexural Strength

$$RF_{7M2} = \{ \phi Mn - [1.3 \times (M_D + M_{Dcomp}) + M_s]\} / [1.3 \times M_{LM2} \times (1 + Impact)]$$

RF_{7M2} = 2.16

Shear Strength

$$RF_{8M2} = \{ \phi V_n - [1.3 \times (V_D + V_{Dcomp}) + V_s]\} / [1.3 \times V_{LM2} \times (1 + Impact)]$$

RF_{8M2} = 1.99

Prestressing Steel Tension

$$RF_{9M2} = (0.9 \times fstar_y - (f_{ds} + f_{dscomp} + F_{ps} + F_s)) / f_{sM2}$$

RF_{9M2} = 13.19

3-Unit Vehicle
Flexural Strength

$$RF_{7M3} = \{ \phi Mn - [1.3 \times (M_D + M_{Dcomp}) + M_s]\} / [1.3 \times M_{LM3} \times (1 + Impact)]$$

RF_{7M3} = 2.51

Shear Strength

$$RF_{8M3} = \{ \phi V_n - [1.3 \times (V_D + V_{Dcomp}) + V_s]\} / [1.3 \times V_{LM3} \times (1 + Impact)]$$

RF_{8M3} = 2.19

Prestressing Steel Tension

$$RF_{9M3} = (0.9 \times fstar_y - (f_{ds} + f_{dscomp} + F_{ps} + F_s)) / f_{sM3}$$

RF_{9M3} = 15.34

Operating Rating

Michigan #18 Truck

Flexural Strength

$$RF_{7M4} = \{ \phi Mn - [1.3 \times (M_D + M_{Dcomp}) + M_s]\} / [1.3 \times M_{LM4} \times (1 + Impact)]$$

RF_{7M4} = 2.16

Shear Strength

$$RF_{8M4} = \{ \phi V_n - [1.3 \times (V_D + V_{Dcomp}) + V_s]\} / [1.3 \times V_{LM4} \times (1 + Impact)]$$

RF_{8M4} = 2.00

Prestressing Steel Tension

$$RF_{9M4} = (0.9 \times fstar_y - (f_{ds} + f_{dscomp} + F_{ps} + F_s)) / f_{sM4}$$

RF_{9M4} = 13.19

Created by: LYL
Checked by: Arth 0 10/31/08
Date: 9/9/08

Summary

Load Rating Result

Inventory Rating	Fed Level	Michigan Legal Level 1-unit	2-unit	3-unit	TR # 18	
RF_5	RF_7	RF_{7M1}	RF_{7M2}	RF_{7M3}	RF_{7M4}	**Flexural Strength**
RF_6	RF_8	RF_{8M1}	RF_{8M2}	RF_{8M3}	RF_{8M4}	**Shear Strength**
$\min(RF_{1\text{-}4})$	RF_9	RF_{9M1}	RF_{9M2}	RF_{9M3}	RF_{9M4}	**Service Load**

Inventory Rating	Fed Level	Michigan Legal Level 1-unit	2-unit	3-unit	TR # 18	
1.97	3.28	3.28	2.16	2.51	2.16	**Flexural Strength**
1.54	2.57	2.69	1.99	2.19	2.00	**Shear Strength**
2.56	20.02	20.02	13.19	15.34	13.19	**Service Load**

Controling = **1.54** > 1

OK

Weight Limit Result

Inventory Rating	Fed Level	TR # 18	
$RF_5 \times W_{MF}$	$RF_7 \times W_{MF}$	$RF_{7M4} \times W_{MM4}$	**Flexural Strength**
$RF_6 \times W_{VF}$	$RF_8 \times W_{VF}$	$RF_{8M4} \times W_{VM4}$	**Shear Strength**
$\min(RF_{1\text{-}4}) \times W_{MF}$	$RF_9 \times W_{MF}$	$RF_{9M4} \times W_{MM4}$	**Service Load**

1-unit Vehicle	2-unit Vehicle	3-unit Vehicle	
$RF_{7M1} \times W_{MM1}$	$RF_{7M2} \times W_{MM2}$	$RF_{7M3} \times W_{MM3}$	**Flexural Strength**
$RF_{8M1} \times W_{VM1}$	$RF_{8M2} \times W_{VM2}$	$RF_{8M3} \times W_{VM3}$	**Shear Strength**
$RF_{9M1} \times W_{MM1}$	$RF_{9M2} \times W_{MM2}$	$RF_{9M3} \times W_{MM3}$	**Service Load**

tons

Inventory Rating	Operating Rating Fed Level	TR # 18	
70.7	118.1	166.4	**Flexural Strength**
55.4	92.5	154.1	**Shear Strength**
92.2	720.7	1015.4	**Service Load**

1-unit Vehicle	2-unit Vehicle	3-unit Vehicle	
137.77 ton	163.58 ton	193.59 ton	**Flexural Strength**
112.84 ton	150.37 ton	168.50 ton	**Shear Strength**
840.80 ton	998.31 ton	1181.46 ton	**Service Load**

Note: Report the lowest #18 truck Load Rating in line 64M.
Federal Rating are reported in metric ton, Michigan rating are reported in US ton.

Inventory Rating	Operating Rating Fed Level	Operating Rating Michigan Truck 18
50.3 ton	83.9 ton	154.1 ton